SEDIMENT QUALITY AND BIOLOGICAL EFFECTS IN SAN FRANCISCO BAY

BAY PROTECTION AND TOXIC CLEANUP PROGRAM

FINAL TECHNICAL REPORT

California State Water Resources Control Board
Division of Water Quality

San Francisco Bay Regional Water Quality Control Board

California Department of Fish and Game
Marine Pollution Studies Laboratory

California State University
Moss Landing Marine Laboratories

University of California, Santa Cruz
Institute of Marine Sciences

August, 1998

SEDIMENT QUALITY AND BIOLOGICAL EFFECTS IN SAN FRANCISCO BAY

BAY PROTECTION AND TOXIC CLEANUP PROGRAM

FINAL TECHNICAL REPORT

Authors:

John W. Hunt, Brian S. Anderson, Bryn M. Phillips, John Newman, Ron S. Tjeerdema
Institute of Marine Sciences, University of California, Santa Cruz

Karen Taberski
San Francisco Bay Regional Water Quality Control Board

Craig J. Wilson
Division of Water Quality, California State Water Resources Control Board

Mark Stephenson, H. Max Puckett
Marine Pollution Studies Laboratory, California Department of Fish and Game

Russell Fairey and James Oakden
Moss Landing Marine Laboratories

EXECUTIVE SUMMARY

Study Objectives

The Bay Protection and Toxic Cleanup Program (BPTCP) was established by the California State Legislature in 1989 with four major goals:

1) To provide protection of present and future beneficial uses of the bay and estuarine waters of California;
2) To identify and characterize toxic hot spots;
3) To plan for toxic hot spot cleanup or other remedial or mitigation actions; and
4) To develop prevention and control strategies for toxic pollutants that will prevent creation of new toxic hot spots or the perpetuation of existing ones within the State's bays and estuaries.

These goals are being addressed through activities in each of the coastal Regional Water Quality Control Boards, including that representing the Bay Region. BPTCP program activities in the San Francisco Bay Region have included initiating the Regional Monitoring Program and conducting studies of fish tissue contamination (as described in the Introduction section of this report). The BPTCP has also implemented regional monitoring studies to identify toxic hot spots. The four major objectives of BPTCP monitoring in the San Francisco Bay Region, as described in this report, are:

1) To identify locations in enclosed bays, estuaries, or the ocean that are potential or candidate toxic hot spots;
2) To determine the extent of biological impacts in portions of enclosed bays and estuaries not previously sampled (areas of unknown condition);
3) To confirm the extent of biological impacts in enclosed bays and estuaries that have been previously sampled; and
4) To assess the relationship between toxic pollutants and biological effects.

The focus of BPTCP monitoring in San Francisco Bay has been to conduct sediment quality assessments in several phases: 1) Approximately 100 reports were evaluated for previous information on water and sediment quality; 2) A large number of bay and wetland sites were surveyed in the Pilot Regional Monitoring Program (PRMP), which also included a methods validation study along a pollution gradient; 3) A reference site study was completed that evaluated ambient conditions in the Bay, and evaluated toxicological and statistical methods for differentiating polluted sites and reference conditions, 4) Approximately 127 stations from throughout the region (selected on the basis of previous information and PRMP results) were screened for sediment toxicity and/or chemistry; and 5) A number of sites that exhibited toxicity and/or elevated chemistry were resampled for additional biological and chemical analyses to confirm previous results. This confirmation survey incorporated three components commonly known as the sediment quality triad: toxicity testing, chemical measurement, and benthic community analysis. Additional samples were collected at selected confirmation sites to estimate the bioavailability of sediment-associated chemicals. Concurrent with this phased sediment monitoring effort, a study was conducted in 1994 to determine chemical concentrations in fish tissues. The results of that study were the basis for a subsequent public health advisory for fish consumption in the Bay and Delta.

Tasks Accomplished

This report describes the results of BPTCP sediment monitoring activities in the San Francisco Bay Region to identify toxic hot spots. During the screening phase of this study, 127 sites that had been identified in previous investigations were screened for sediment toxicity. Since funding constraints precluded comprehensive assessments at each screening site, toxicity testing was used as the screening tool. Toxicity tests are direct, precise indicators of the integrated effects of sediment contaminants, and they provide information about biological impacts of pollutants, information difficult to discern solely from chemical measurements. Generally, two toxicity tests were used at each screening site: a solid-phase sediment test with benthic amphipods, and a sediment porewater test using developing embryos of sea urchins. As methodological improvements were incorporated during the study, some screening samples were tested with sea urchins exposed to the sediment-water interface instead of porewater.

After reviewing the screening data and information from previous studies, a number of stations were resampled during the confirmation phase of the study. Twelve stations were resampled and analyzed with the sediment quality triad, including two toxicity tests, sediment chemistry, and benthic community analysis. Ten of these stations were also analyzed for bioaccumulation, using 28-day laboratory exposures with the clam *Macoma nasuta*. A total of 46 stations were screened for a broad suite of trace metal and organic compounds, and a total of 143 samples were analyzed for mercury and PCBs, chemicals that were identified as elevated in fish tissues in the Bay (Fairey et al., 1997) and were the subject of a fish consumption health advisory. An additional 15 stations were resampled and tested with sea urchin larvae in sediment-water interface exposures, because their screening samples exhibited toxicity only in sea urchin porewater tests that were accompanied by elevated sulfide or ammonia concentrations.

In order to provide additional information about potential toxic hot spot sites, linear transects (gradients) were sampled at some confirmation stations to evaluate relationships between sediment chemistry and biological effects at these sites. Phase I sediment Toxicity Identification Evaluations (TIEs) were conducted at two sites, and an abbreviated sediment-water interface TIE was conducted at a third site to investigate possible causes of sediment toxicity.

Major Findings

After screening 127 stations from throughout the Bay area, and returning to 12 of those for more intensive analysis during the confirmation stage, this study successfully identified several highly polluted locations that exhibited adverse biological effects. The study also indicated that 21% of all samples tested were toxic to amphipods, 31% of porewater samples were toxic to sea urchin embryos, and 33% were toxic to sea urchin embryos exposed at the sediment-water interface. Statistical analyses indicated a number of chemicals that were both correlated with biological effects and found at concentrations exceeding sediment quality guideline values.

A number of sites had high concentrations of chemical mixtures, numerous chemicals with concentrations above sediment quality guideline values, and significant biological effects. These sites were categorized based on the magnitudes of chemical concentrations and effects. The sites exhibiting highest chemical concentrations and greatest biological effects included: Stege Marsh, Mission Creek, Islais Creek, Point Portrero (notable for extremely high PCB and mercury concentrations), Pacific Drydock, Castro Cove, Peyton Slough, and San Leandro Bay.

Mercury and total PCBs were identified in a California Office of Environmental Health Hazard Assessment health advisory on consuming fish caught in San Francisco Bay and the Delta. These chemicals were found at elevated concentrations in a number of sediment samples analyzed in this study. PCBs, but not mercury, were accumulated to high levels in clams exposed to 6 of 10 sediment samples tested. Mercury, but not PCBs, was found to correlate with toxicity to sea urchins in sediment-water interface exposures.

In Principal Components Analyses (PCA), sediment quality guideline quotient means (ERMQs) and number of chemicals exceeding guideline values covaried negatively with biological indicators (increasing concentration associated with decreasing biological function). Chemicals identified by PCA that also exceeded guideline values and were significantly correlated with adverse biological effects included: total chlordanes and 2-methylnaphthalene (with amphipod toxicity); cadmium, copper, silver, and zinc (with sea urchin porewater toxicity); and cadmium, copper, and zinc (with sea urchin SWI toxicity).

Sediment quality guidelines, as described in the Methods section, have been derived empirically from a large number of studies nationwide to indicate chemical concentrations often associated with adverse biological effects. The use of guideline values allows simple comparisons of sample concentrations to those observed in numerous other studies. This comparison is useful for perspective, but does not necessarily indicate that chemicals with concentrations above guideline values are responsible for any observed impacts. Only site-specific intensive investigations, using TIEs and other toxicological methods, can be used to determine causal relationships. In the present study, numerous chemicals were found at concentrations exceeding guideline (ERM) values. Of these, chlordanes, PCBs, DDTs, PAHs, dieldrin, copper, mercury, lead and zinc were commonly found above ERMs. Hexachlorobenzene and chlorpyrifos, for which ERM values have not yet been derived, were often found at concentrations above the 90^{th} percentile of the statewide BPTCP sediment chemistry data base. Combined concentrations of chemical mixtures were high at many sites, with 9 sites having mean ERM quotients above the 95^{th} percentile of the statewide distribution.

In tests of 10 samples from the Bay, exposed clams accumulated elevated tissue concentrations of nine chemicals or chemical classes: copper, lead, total chlordanes, total DDTs, dieldrin, total PCBs, LMW PAHs, HMW PAHs, and total PAHs. The identification of these chemicals was dependent on the particular samples tested, the physiology of the clam *Macoma nasuta*, and the 28-day exposure period of the laboratory tests.

The data provided in this report represent a significant body of information to assist in management efforts to identify and remediate toxic hot spots in San Francisco Bay. A number of sites were identified as having elevated pollutant concentrations and severe biological impacts. Determination of spatial extent and development of information relevant to pollutant source control at these sites may require additional investigation. A number of other sites demonstrated elevated chemical concentrations without severe acute toxicity, and still other sites had toxic sediment without having elevated concentrations of measured chemicals. These sites may warrant further studies of chronic effects and/or investigations to determine the likely causes of observed biological impacts.